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arrangement of belts in the vicinity of the spot is somewhat different. Small round white spots are to be seen on the southern hemisphere, but they are smaller and less conspicuous than they were last summer. Other less obvious changes need not be referred to here, as many more observations of *Jupiter* will be possible during the present opposition. It would seem, on the whole, that the surface features of *Jupiter* indicate less activity in the internal forces of the planet than was manifest a year ago.

Lick Observatory,
August 31, 1890.

Some Experiments relating to the Photometric Comparison of Points of Light with Objects of Sensible Area. By Edmund J. Spitta.

In November 1887 a paper was read before the Society, "On the Appearances presented by the Satellites of Jupiter during Transit," when attention was directed to the fact that whilst using the wedge-photometer during some experiments and measures upon *Jupiter* connected therewith, an unaccountable loss of light was proved to exist when a point of light, such, for instance, as was exhibited by a satellite, was photometrically compared with an object of sensible area like *Jupiter*. For the past three years or more, at the instigation primarily of Professor Pritchard, a protracted research has been in progress to ascertain the cause or causes of such loss, whether physical or physiological; but the subject having extended itself so much further than was anticipated, it has been found necessary to describe the results under three heads: (1) Those connected with the constant of absorption of the wedge-photometer; (2) The objections to employing such a form of photometer when dealing with objects of sensible area and the means devised to remedy the same; and (3) experiments which show peculiar idiosyncrasies in the photoperceptive faculty of the eye when viewing different-sized areas. The object of this communication is to set forth the experiments connected with the last two divisions of the subject.

The results arrived at concerning the first division were presented to the Society in a paper read in March last, but during the progress of the experiments connected therewith, another source of error was thought possibly to cause the loss of light when comparing a point of light with an area in the wedge-photometer. It was this. A point of light, from its very definition, implies that no sensible portion of a wedge is occupied in its passage, but it requires very little thought to perceive that when an area of sensible dimensions is being dealt with this is by no means the case. Moreover, if the area be considerable, the light emanating from its lateral edges impinges on a different thick-

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ness of the glass. To supply a correction under these circumstances was not easy, hence the removal of this possible source of error was arrived at by devising an instrument to which the name of "compound wedge-photometer" has been given, and which consists of two thin wedges of neutral tinted glass, made to slide past one another with a uniform rate of motion. Any amount of density (within certain prescribed limits) can be obtained, although a uniformly absorptive area in all parts of the field is rigidly maintained.*

As it became necessary to obtain the coefficient of absorption of this instrument with great precision for use in the experiments to be immediately related, it should be here mentioned that it was evaluated in the following manner.

Each wedge removed from its cell was separately tested for equality in density by the polarising method which peculiarly lends itself to this operation. Both were considered satisfactory. The glasses were then returned to their respective positions, and the coefficient ascertained by employing a small hole illuminated by light immediately under the control of an Abney photometer. By this arrangement the wedge was evaluated by the same method as that employed in its use, which, it would seem, is more philosophical than to evaluate it by equalising lights and use it by a method depending upon extinctions. The artificial star was placed at a distance of 90 inches, and the initial intensity of its light at first arranged so that a ratio of 1 : 8 employed about a third of the available length of the instrument. The value in magnitude over this portion for each half-inch division was found to be ·86. The initial light was then raised and arranged so as to employ the middle third of the wedge, overlapping a small portion of that previously examined. The value here obtained was ·88 mag. for each half-inch division. The last third similarly treated yielded a coefficient for the same length of ·84. These small differences were attributed to errors of observation rather than to any difference in the absorptive power of the glass, hence the mean (·86 mag.) for each half-inch division was adopted in the experiments which follow.

It was found, however, even with the new method of obtaining the coefficient and the new instrument, that a sensible loss of light occurred when a point of light was compared with an area of known dimensions. It was then decided to conduct a further series of experiments which form the third division of the subject, with holes of different sizes, and to ascertain, if possible, the minimum diameter of image at which this loss of light became sensible.

The holes were measured by a parallel wire micrometer, the value of whose screw was first carefully determined, and their respective diameters are given in the following table. The numbers in the first column are for identification only.

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* For further information as to details of construction see "A Compound Wedge-Photometer," *Proc. Roy. Soc.*, vol. xlvii.

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TABLE I.

Number 1	·0020 inch	Number 7	·0131 inch
" 2	·0227 "	" 8	·0144 "
" 3	·0027 "	" 9	·0316 "
" 4	·0071 "	" 10	·0460 "
" 5	·0180 "	" 11	·0626 "
" 6	·0380 "		

Number 3 being so very nearly the same size as the standard, was not used.

The ratio of the light passing through each of the holes with respect to the first, chosen as the standard, was then obtained with the compound wedge-photometer, and the results are set forth in Table II.

TABLE II.

1.	2.	3.	4.	5.	6.	7.
I.	4	2·72	12·48	1 : 3·58	2·77	12·82
II.	7	4·01	40·37	1 : 6·56	4·08	43·03
III.	8	4·24	49·89	1 : 7·23	4·29	52·27
IV.	5	4·81	84·00	1 : 9·10	4·79	82·81
V.	2	5·19	119·20	1 : 11·36	5·27	129·04
VI.	9	5·70	190·60	1 : 15·60	5·96	243·36
VII.	6	5·636	179·64	1 : 19·00	6·39	361·00
VIII.	10	6·30	400·25	1 : 23·00	6·81	529·00
IX.	11	6·261	319·50	1 : 31·30	7·48	976·60

In column 1 is the distinguishing number affixed to the observation for future reference; in column 2 the identifying number of the hole compared with the standard; column 3 gives the "wedge-interval" converted into magnitude, followed in the next by the same converted into light-ratio; column 5 supplies the real ratio of the diameters from direct measurement, which in columns 6 and 7 is converted into magnitude and light ratio respectively. The holes were all placed at 90 inches from the observing telescope, an achromatic of 2·375 inch aperture with a 24·75 inch focus, armed with an ocular magnifying 46 times.

On examining this table it is seen that until the ratios reached that of 1 : 11, in other words, until the holes, as a matter of fact, had an angular value of more than about 40′ to the eye, they acted as points of light, making due allowance for errors of observation.

The figures in the table are the mean of two closely accordant sets of observations, with the exception of number IX., which is the mean of three.

To understand the results obtained was very difficult, seeing

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that every care had been exercised in their execution. During their consideration several other minor experimental measures were made, such as proving whether, with very small holes, readings were similar if the intensity of the light was halved by the Abney photometer but the area doubled. This was done as a check upon the evaluation of the wedge, and it is satisfactory to state that the results obtained were exceedingly accurate, allowing a small error for observation. Of the remainder that were carried out, the following five are selected, as they serve to show successive steps in the process which led to the explanation shortly to follow.

(i) Observation VIII. with the ·046 hole was repeated, but with a higher power ocular; it was found that the enlargement of the image appeared to produce a most striking and important loss in the resulting ratios, amounting as a matter of fact to ·3 magnitude.

(ii) The "wedge reading" of the extinction of the standard was taken with a low power ocular, and then with one of higher power. The difference between them was not more than would be accounted for by the extra thickness of the shorter focussed lenses; hence the teaching of this experiment appeared exactly opposite to that of the preceding.

(iii) The "wedge reading" for extinction was taken for a small hole about ·046 inch in diameter. It was then half-covered and the reading taken again; the difference between these readings gave a ratio of 1 : 87, instead of 1 : 5 as might have been expected, and this after repeating the observations a second time. This seemed very difficult to understand, especially as in the next experiment

(iv) Reducing the intensity by one half in a very small hole (the standard was used) the photometer gave results in accordance with what should have been found.

(v) The last experiment was unique. Two new holes ·047 inch in diameter were obtained. Each was covered with goldbeater's skin. One was left untouched, but to the other was affixed, approximately in its centre, a small disc of brass ·025 inch in diameter, very approximately equivalent to the length of the radius of the larger hole. When the light issuing through the two holes was compared, it was found the spotted area appeared to transmit less light than should be accounted for by the area occupied by the interposed brass disc.

It became evident on consideration that the actual powers of perception in the eye, physiologically speaking, must be a highly important factor in the question at issue, as it seemed very evident the piece of brass in the last experiment occluded more light, so far as was perceived by the brain, than its actual area seemed scientifically to warrant.

When the eye is directed towards an object it is needless to state the image always falls upon the fovea centralis, the central pit which is always present in the macula lutea or yellow spot

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of the eye.*† The investigations of Helmholtz, Max Schultze, Henle, Müller,‡ and others, have led very distinctly to the belief that the perceptive faculty of the eye varies very greatly and in ill-defined zones around the fovea, which is by far the most highly sensitive portion of the whole retina. Indeed, Johannes Müller, of Berlin, goes still further, for he states that the perceptive faculty of the eye not only varies in the zones previously mentioned, around the fovea, but even may be said to represent a kind of mosaic, for in the zones themselves it is very unequally diffused. Taking this into consideration then, it became very evident the diameter of the images of these holes upon the retina, or their angular value as seen by the eye, was a most important factor in their capability of perception by the brain. Consequently the diameter of the images of these holes on the retina, when seen with the telescope (of 24·75 inch focus) placed at a distance of 90 inches, with an ocular of magnifying power 46, was computed; the latest value for the focal length of the average eye, viz., ·892 inch, being that employed. The figures obtained are set forth in Table III., side by side with their angular value as seen by the eye:—

TABLE III.

Hole No.		Inch.		°	′	″
Hole No.	1	·000943	Angular value			4
,,	2	·010761	,,		40	15
,,	3	·001141	,,			4
,,	4	·002872	,,		12	16
,,	5	·008206	,,		31	46
,,	6	·017438	,,	1	6	42
,,	7	·005967	,,		23	00
,,	8	·006556	,,		25	18
,,	9	·014272	,,		55	58
,,	10	·020962	,,	1	20	30
,,	11	·028455	,,	1	49	38

The most recent measures of the fovea centralis in a large number of subjects show that the pit is slightly elliptical, the short axis varying from ·00788 to ·01576 inch, the mean being about ·01182, which implies that the limit of acute vision lies

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* It is somewhat curious that the macula lutea is absent in the ox.

† It is interesting to convey to the mind an idea how the size of the fovea limits the area of the most acute vision in daily life. It may be gathered from the fact that such an area lies within the prescribed limits of a halfpenny held at a distance of about 74·5 inches, which implies that the angular value for vision of the highest order is contained within an angle of about 40′, as will be seen hereafter.

‡ Max Schultze, article, "Retina," in Stricker's *Handbook of Histology*; Helmholtz, *Handbuch der Phys. Optik*; Henle, *Quain's Anatomy*, and Henle and Meissner's *Bericht*; Müller, see Huxley's *Crayfish*.

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within an angle of about 40′. It is very evident, then, from a comparison of these figures with those in Table II., that the probable reason the first four holes behaved as points of light (for the figures varied nearly as the areas) arose from the fact that the images on the retina fell within the prescribed limits of my fovea, and so within my bounds of acute vision; and that the cause of the falling off of the ratio obtained in observation V. was due to the fact that, owing to the angle subtended being greater than 40′, the diameter of the image of that hole was just beginning to exceed the limits of the pit, a small portion of it falling upon a less sensitive portion of the retina. Hence the total magnitude of the sensuous impression conveyed to the sensorium was less in quantity than if the whole image had fallen entirely within the fovea. The same reasoning applies, but more strikingly still, to the ratios in the observations following, the angles subtended being still greater, the images of the holes were correspondingly larger, and consequently the loss more pronounced. I submit, then, that the cause of the loss of light noticed when *Jupiter* was photometrically compared with his satellites was due to the fact that the angular value of the Jovian image with the ocular employed was greater than 40′, and consequently was due to a physiological idiosyncrasy in the perceptive faculty of the eye.*

I am prepared to admit that the consequence of this is far-reaching, for it is evident, to obtain a veritable photometric comparison in such cases, the images of each object under observation must not subtend an angle of more than 40′—in other words, be small enough to fall within the limits of the observer's fovea centralis.

With this explanation in view, it is not difficult to understand the results obtained in the experiments numbered from one to five.

In the first (I.), the angular value of the larger hole, greater than 40′, became still greater by the subsequent magnification, so the falling off in the total amount of the sensuous impression conveyed to the brain for perception might be reasonably expected to follow.

With (II.) it was different. The enlarged images caused no falling off in the ratios, because they were in each case smaller than the prescribed limit of distinct vision.

In the case of (III.) the half image appeared relatively brighter than the whole, because the ratio of the amount of light falling upon my fovea in the second instance bore a greater proportion to the image in that case to that which it did in the first. In other words, a greater proportion of the image fell upon the extra sensitive pit when the eye was looking at the semi-lune to what it did when viewing the entire one.

With respect to the last observation (V.), it is submitted the theory is more supported than before, for the angular value of

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* From a careful consideration, the fovea centralis of my own right eye is very slightly below the average diameter.

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the brass disc was such that its image just overlapped the limits of my fovea; hence the spotted area gave to the brain a far less conception of light than it should have, which arose from the fact that the most exciting part of the image was withdrawn.

At this juncture a crucial experiment suggested itself. If the loss of light really did depend upon the size of the image on the retina, then even the pronounced loss which occurred in observation VI., table II., would not be felt if the two holes were viewed without any telescope whatever, for it is patent the images of the two holes must fall within the area of my acute vision. This was done and it is not a little satisfactory to state that the ratios came out very approximately in accordance with the figures given in column 7—in other words, the two holes acted as points of light.

It is not without interest also to mention that the probable cause of the great difficulty experienced by many, including myself, in learning the use of the wedge photometer, is explained by much the same reasoning as the loss of light. Nothing but continued practice will enable the observer to hold his eye sufficiently steady to keep the image of the fading star rigidly within the area of his fovea centralis. But it might be argued by those adhering to predilected orthodoxy, that the explanation submitted lacks support in practice, owing to the fact that it is often supposed to be easier to see a point of light by *oblique* or *indirect* vision than with *direct*. But it is needless to point out that such is more apparent than real, for it must not be forgotten that a retina wearies as much as any other part of the human organism, and, although the fact of suddenly employing a fresh, though perhaps a really weaker, portion of the sensitive membrane would for the moment bring about a more patent effect than the further use of the wearied part, still that does not show that the lateral edges of the retina are intrinsically of greater perceptive power than the fovea. To bear this out it is very easy to make the attempt which I had tried when learning the use of the wedge, long before I was engaged upon these experiments, viz. to direct the eye by *indirect* vision to a faint object, allowing the most intense attention to be employed; the advantage is manifest at once in the seeing, when the observer turns his eye upon the object *directly*. There is no comparison.

In conclusion it should be remarked that, although this idiosyncrasy in the subject of physiological optics, which has such an important bearing in photometrical astronomy, in no way affects the comparison of areas *of the same dimensions*, still it equally applies to *any* form of photometer when points of light are photometrically compared with objects of sensible area. And further, that if any law for the falling off of the light with increasing area had been obtained, it would not be of practical value, as it would probably only apply to the individual observer himself.

Ivy House, Clapham Common,
November, 1890.

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On some Celestial Photographs recently taken at Sydney Observatory. By H. C. Russell, B.A., F.R.S.

I have recently obtained a large portrait lens by Dallmeyer (No. 8 in D Series), with lenses having a clear aperture of 6 inches, with the object of taking pictures of the southern part of the Milky Way. While waiting for the lens which is to be used in taking photographs of the part of the sky allotted to Sydney by the Paris Conference, the portrait lens has been attached to the mounting of that telescope and used for taking the desired pictures since the end of June. The weather has, however, been unusually wet and cloudy, and the work has been delayed thereby. Up to the present time pictures have been obtained which include all the bright part of the Milky Way from 10 hours to 17 hours R.A. Also of the Nubeculæ Major and Minor of the bright region in *Sagittarius*, including 8 Messier, and of several other parts.

I send with this positives on glass of six of these photographs covering the Milky Way from 10^h to 17^h, and paper prints of the same. It will be noted that the definition is only good over the central parts. Attempts were made by bringing the lenses closer together to improve the definition, but without success, and the lenses have been used in the mounting supplied by the maker. The plates cover 14° × 10°.

The exposure after many experiments was fixed at 3 hours, so that stars of 15 or, in some cases, 16 mag. (Herschel) should be included.

In 3 hours also a faint picture of the nebula about η *Argûs* has been obtained. It shows decided indications of structure, and on the south preceding side of η, two parallel wreaths of nebulæ are distinctly curved, which may be faintly seen in the positive and in the silver print now forwarded; in the negative it is much better seen. η itself seems to be in another spiral wreath, and the faint markings taken together suggest a structure something like that of the spiral nebula, H 1173. The photograph is much under-exposed for the purpose of delineating the nebula, and, unfortunately, when the need for an exposure of 4 or 5 hours was discovered, η was too far west to admit of it, and the solution of the question must rest until η is in a more favourable position. It is remarkable how slow this nebula is in fixing its image on the sensitive plate. I have often tried before with other instruments, but always failed to get any trace of the nebulous light on the plate.

In the great dark oval which is shown near the extreme north of Herschel's drawing of the nebula about η *Argûs*, he shows four minute stars of 16th magnitude. In going over his work with a $7\frac{1}{4}$ inch telescope, I saw three of these stars, and in the photograph obtained in 3 hours three are shown in this oval space, which the photograph shows quite void of other light.